Melting of Layered Phases in Colloid-Polymer Mixtures

Arjun G. Yodh, University of Pennsylvania, DMR-0203378

Melting is among the most important phase transitions in nature. In this research we investigate pathways for melting of lamellar or layered phases. In contrast to crystals which have 3-dimensional (3D) order, lamellar phases have one-dimensional (1D) quasi-long-range order. Additionally, while 3D crystals have only one surface with coexisting gas or liquid, the lamellar phase is a microphase separated state in which the entire bulk is spanned by interfaces between immiscible materials. Although these types of layered phases occur frequently in nature, melting transitions of lamellar phases are rarely observed. We have created a novel complex fluid consisting of layers of nanorods separated by polymer rich solvent. We observe the melting transitions of this model system, and show that this process is fundamentally different from the melting of conventional crystalline solids.

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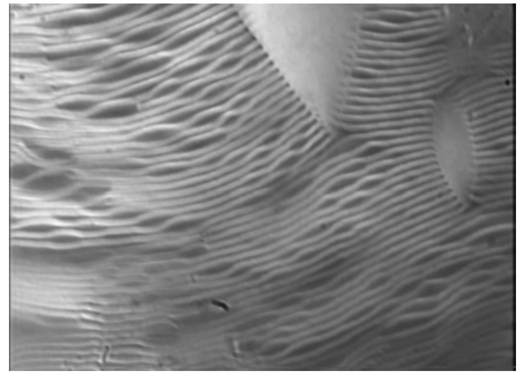
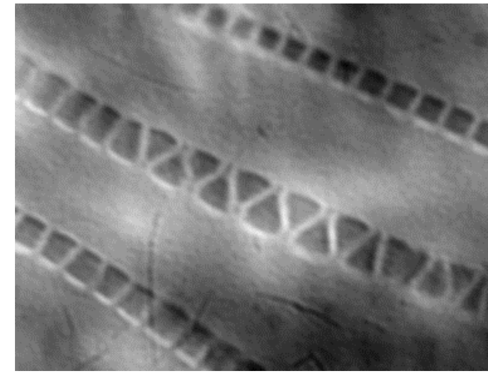
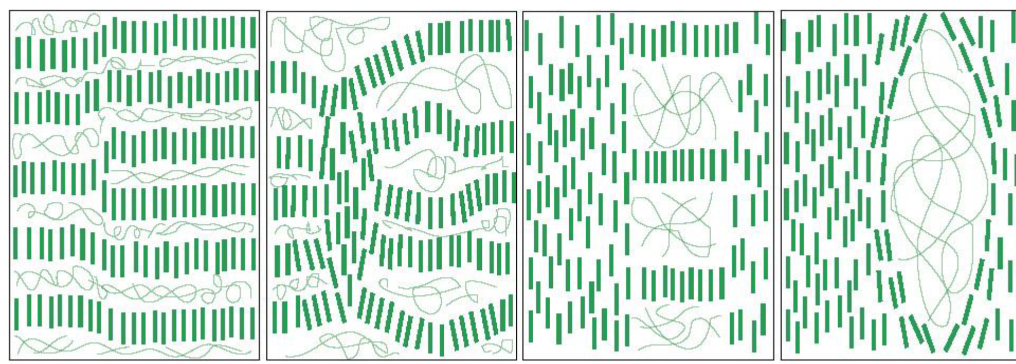




Top Left: Optical microscopy showing the coexistence of many layers of nanorods (white lines) within a nematic liquid crystalline droplet composed of aligned nanorods. The layer spacing is approximately 1 micron. Top Right: Highly swollen layered phases in a nematic liquid crystalline background (cover image of *Physical Review Letters,* July 30, 2004).



Above: Sequence illustrating melting of the lamellar phase into a nematic phase. Notice that nucleation of the nematic droplets occurs at line defects in the layered phase. Rods are straight line segments. Polymers are wiggly lines.

Soft condensed matter physics is concerned with materials such as colloidal particle suspensions, emulsions, polymer solutions, gels, membranes, liquid crystals and mixtures thereof, whose structure and dynamics are strongly influenced by entropy. Soft materials are attractive starting media in photonics and lithography, in high-tech ceramics and in biochemical sensing. Particle additives also offer practical control of fluid rheologies, improving the performances of materials ranging from conventional paints and pastes to motor oils to food and cosmetics. Finally, soft materials experiments are increasingly stimulated by analogies from cell biology, in some cases providing critical insights about mechanisms that arise in crowded cellular environments. They also provide a fascinating testing ground for many-body statistical physics, and for the investigation of entropy, defects, phase transitions and other instabilities. The work on melting of layered phases explores how the dimensionality of a phase (i.e. layered phases are one-dimensional) modifies melting pathways. Our findings impact the understanding and control of a variety of layered materials from cell membranes to emulsion processing.

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Arjun G. Yodh, University of Pennsylvania, DMR02-03378

Education:

- This work was spearheaded by my PhD student Ahmed Alsayed, and my post-doctoral associate, Zvonimir Dogic. Ahmed is finishing up his thesis, and Zvonimir is currently a Research Fellow at the Rowland Institute of Science. Two undergraduates (Sean Lake from Penn and Patrick O'Neil from UC Santa Barbara) also contributed to this research as part of summer REU programs.

Societal Impact:

- Lamellar structures are typically built from amphiphilic molecules such as surfactants, lipids, and block copolymers. These same ingredients play a critical role in cell membranes, and in practical materials such as emulsions and vesicles for controlled drug delivery. Our research on the phase transformations of lamellar structures thus provides insight about membrane biophysics, and provides understanding for control of many practical materials.